Monitoring the Concentration of Fluoride and Other Impurities Across a Purification System

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R&D for LHC Experiments
Background

- Resistive Plate Chambers (RPCs) are a type of muon detector that utilizes gas mixtures to induce avalanche ionization reactions
- Harmful impurities can damage the inside of the detector if they are not properly filtered

Schematic of gas recirculation system at CMS

Gas mixtures must be recycled because they are expensive and may produce greenhouse effects

Typical gas composition for RPC detectors:
- 94.7% Freon ($\text{C}_2\text{H}_2\text{F}_4$) to induce avalanche ionization
- 5.0% Isobutane ($\text{i-C}_4\text{H}_{10}$) for quenching
- 0.3% Sulfur Hexafluoride ($\text{SF}_6$) as a source of electronegativity

Cross-section illustration of the components of the CMS detector
How do we monitor purification systems?

**Ion Selective Electrodes (ISE)**

- Measures potential difference between sample and a standard, then utilizes Nernst Equation to solve for ion concentration
- Used to determine the accumulation of Fluoride ions over time before and after purifier

**Gas Chromatography (GC)/ Mass Spectrophotometry (MS)**

- GC separates gas components in time and quantifies them using chemically treated columns and a thermal conductivity detector (TCD)
- MS identifies components by ionizing and accelerating the sample in a magnetic field. Mass/charge ratios are then determined.
- Coupled together to allow for separation, quantification and identification of gas components
ISE Set-Up

Goal: Monitor the levels of Fluoride build-up over time before and after the purifier

Step 1: Calibrate Electrodes

Solution Fluoride concentration versus Voltage for electrodes

<table>
<thead>
<tr>
<th>Electrode</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>y = 59.70x + 67.52</td>
<td>0.9949</td>
</tr>
<tr>
<td>B</td>
<td>y = 40.12x + 79.03</td>
<td>0.9972</td>
</tr>
<tr>
<td>C</td>
<td>y = 58.73x + 75.896</td>
<td>0.9963</td>
</tr>
<tr>
<td>D</td>
<td>y = 55.06x + 74.749</td>
<td>0.9926</td>
</tr>
<tr>
<td>E</td>
<td>y = 51.82x + 8.4377</td>
<td>0.9967</td>
</tr>
<tr>
<td>Old</td>
<td>y = 56.98x + 105.9</td>
<td>0.9934</td>
</tr>
<tr>
<td>G</td>
<td>y = 46.12x - 120.34</td>
<td>0.9965</td>
</tr>
</tbody>
</table>

Ideal Slope: 56+/-4

Step 2: Troubleshooting

Step 3: Stability Tests

Fluoride Reading for Electrodes A, C, D, and OLD over 26 hours

Fluoride Reading for Electrodes A and D over 140 Hours

Image from Hannainst.com

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Installing ISE Station

The ISE station is now installed and recording Fluoride concentration data.

ISE installed at gas distribution racks

Electrode
Sample gas bubbler

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GC/MS Set Up

Goals:
1. Troubleshoot Systems and couple GC with MS
2. Set up remote valve control
3. Identify new gas impurities before and after the purifier

Schematic of valve controller set-up

Micro gas chromatography machine

Chromatograph

Signal (μV) vs. Time (Sec)
GC/MS Analysis

Sulfur Hexafluoride

Freon

Isobutane
Conclusion

- Gas mixture analysis is used to prevent aging of detector
- ISE, GC, and MS can used to determine the amount, identity, and accumulation of gas system components.

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